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(54) **H-BRIDGE MOTOR DRIVING CIRCUIT**

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(52) **U.S. Cl.** **318/801**; 318/799; 318/800; 318/802; 318/803; 318/700; 388/905; 388/907; 388/907.2; 388/907.5

(58) **Field of Search** 318/799, 800, 318/801, 802, 803, 432, 434, 700; 388/905, 907, 907.2, 907.5

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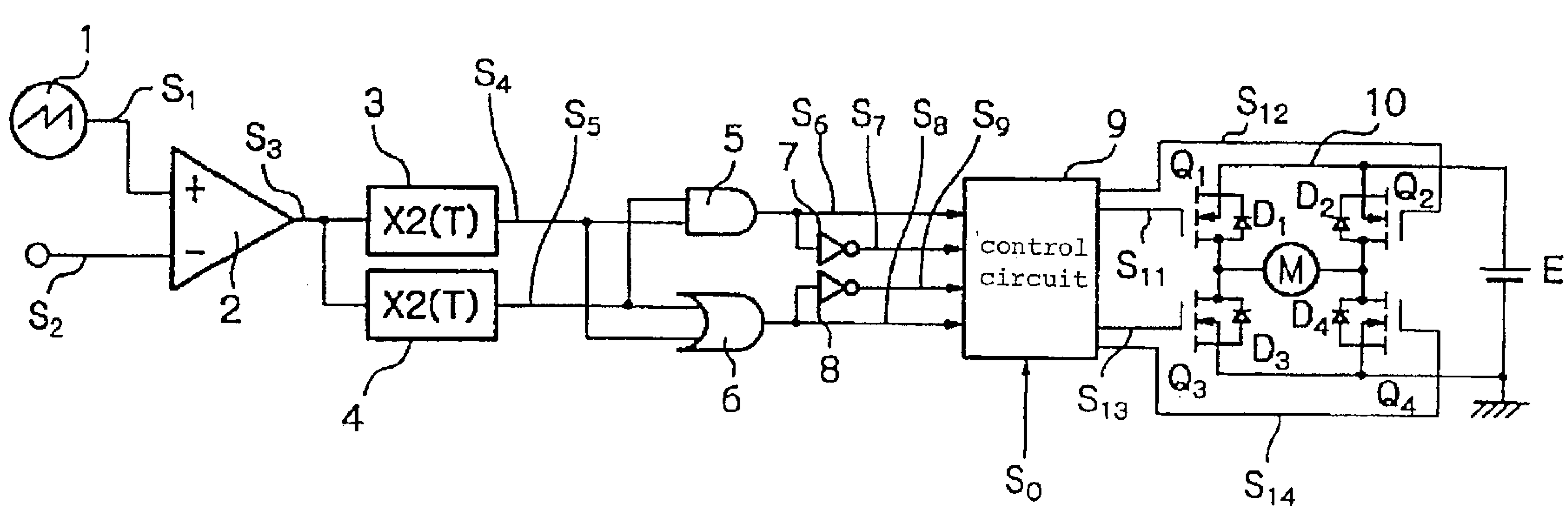
(57) **ABSTRACT**

An H-bridge motor driving circuit has, between a PWM comparator and a control circuit, first and second frequency dividers for frequency-dividing, by 2, an AND gate, OR gate, and first and second and second inverters. During a first period, the first and second MOS transistors are turned on, and the second and third MOS transistors are turned off, caused a current to flow through a motor. During a next second period, the third and fourth MOS transistors are turned on, and the first and second MOS transistors are turned off, causing a regenerative current to flow through the motor. During a next third period, the MOS transistors are turned on and off in the same manner as during the first period, causing a current to flow through the motor. During a final fourth period, the first and second MOS transistors are turned on, and the third and fourth MOS transistors are turned off, caused a regenerative current to flow through the motor.

1 Claim, 4 Drawing Sheets



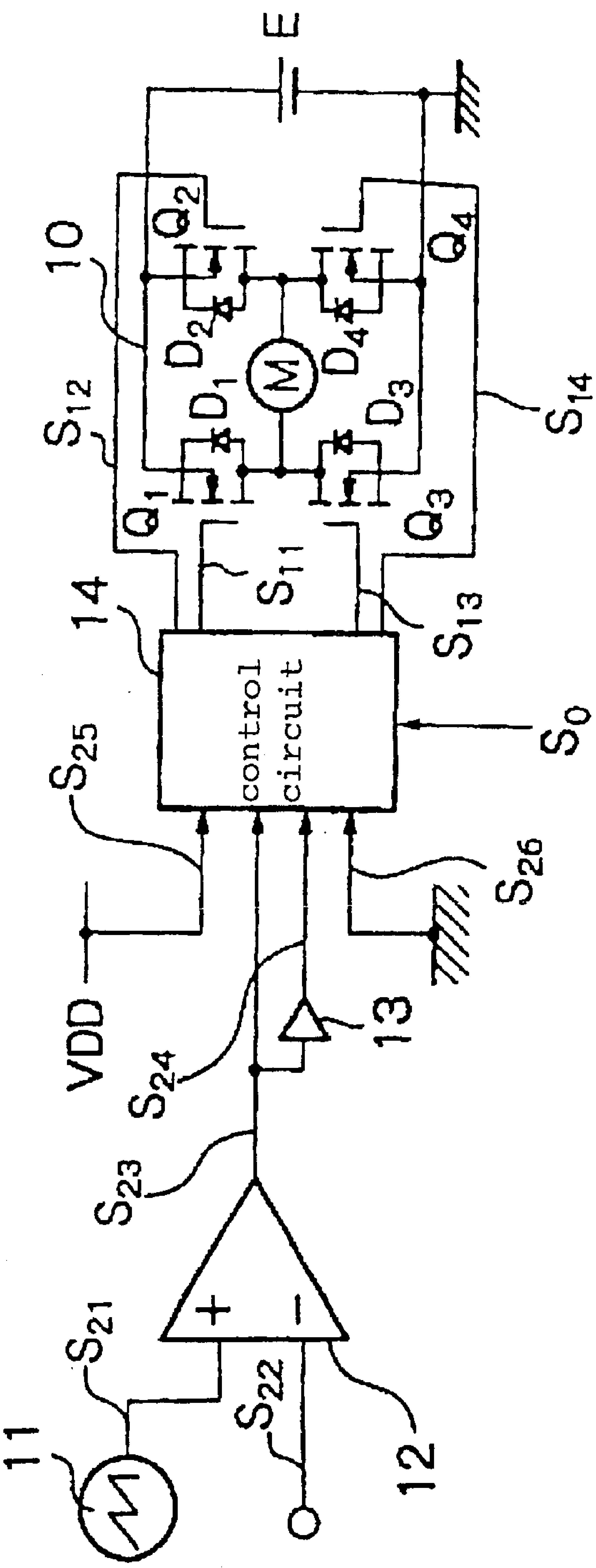


FIG. 1 (PRIOR ART)

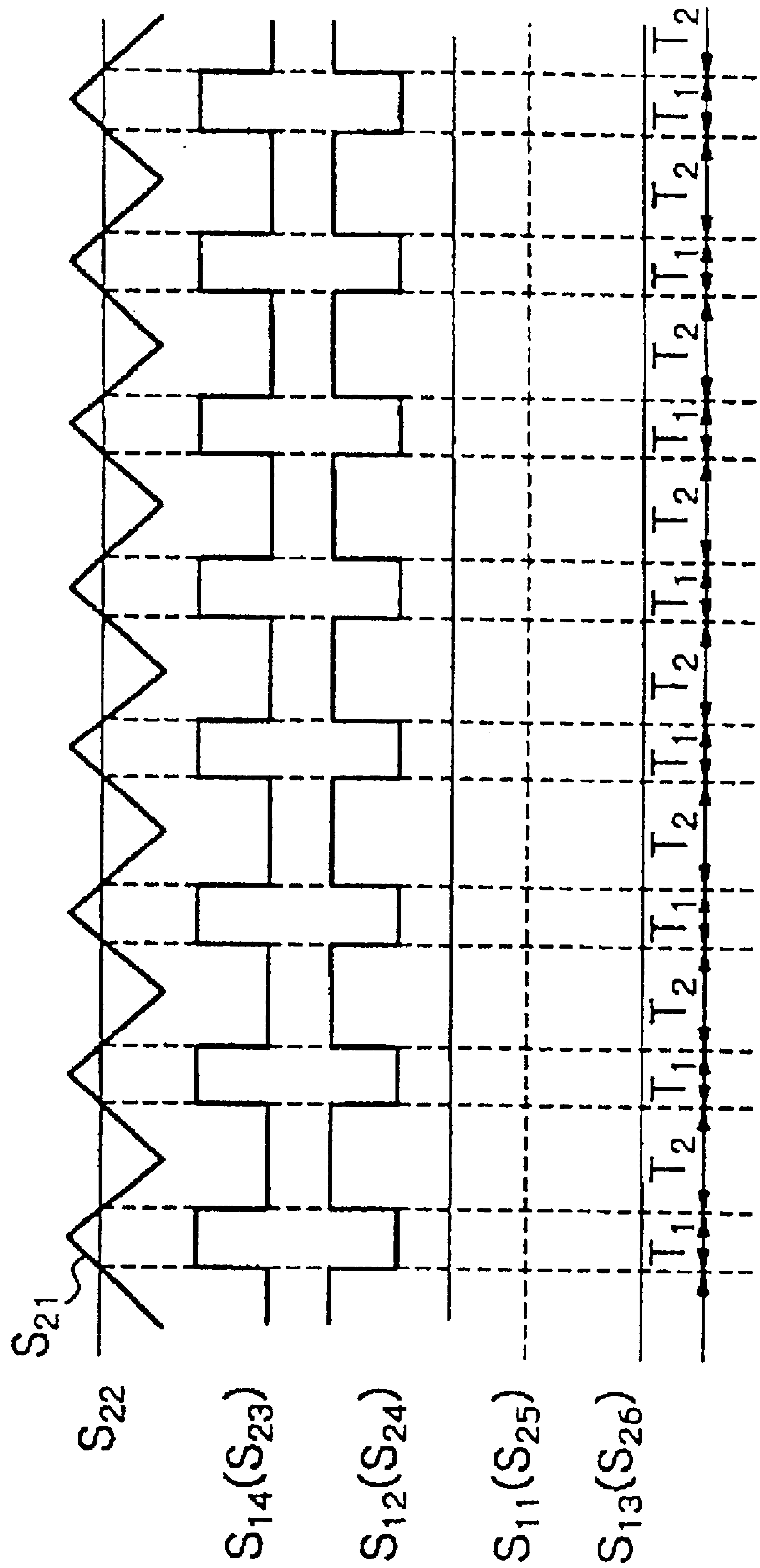
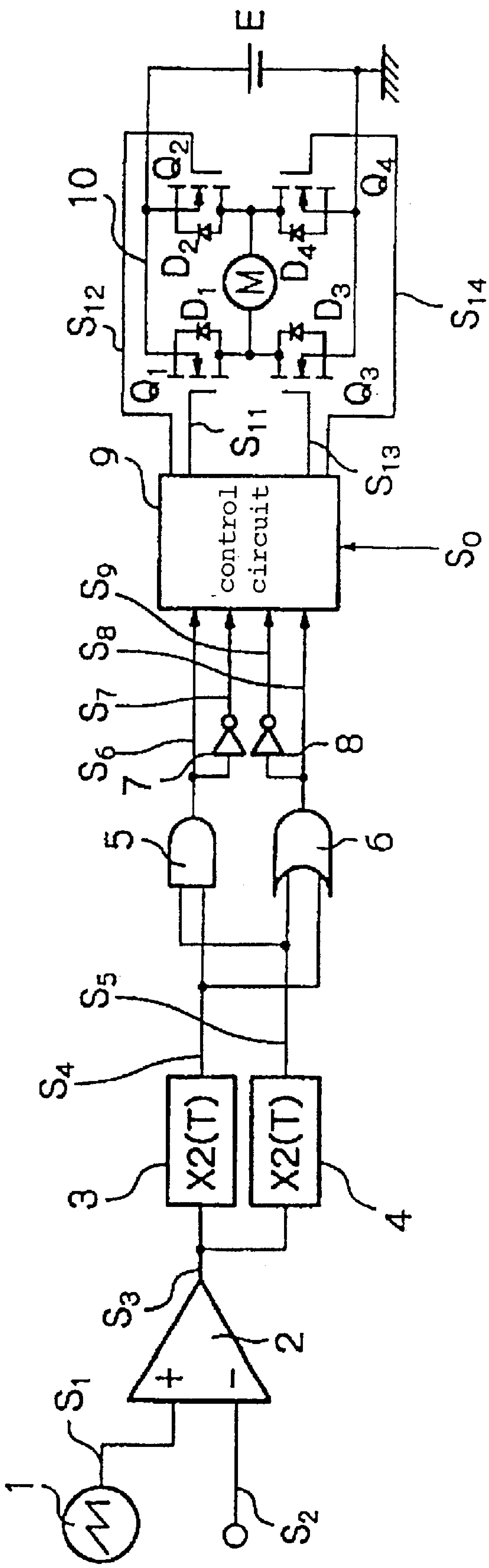


FIG. 2 (PRIOR ART)

FIG. 3


E
10
Q_2
Q_4
D_2
D_4
M
D_1
D_3
S_{12}
S_{14}
Q_1
Q_3
S_{11}
S_{13}
9
control circuit
S_0
S_9
S_8
S_7
S_6
7
8
5
6
S_5
S_4
X2(T)
X2(T)
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S_2

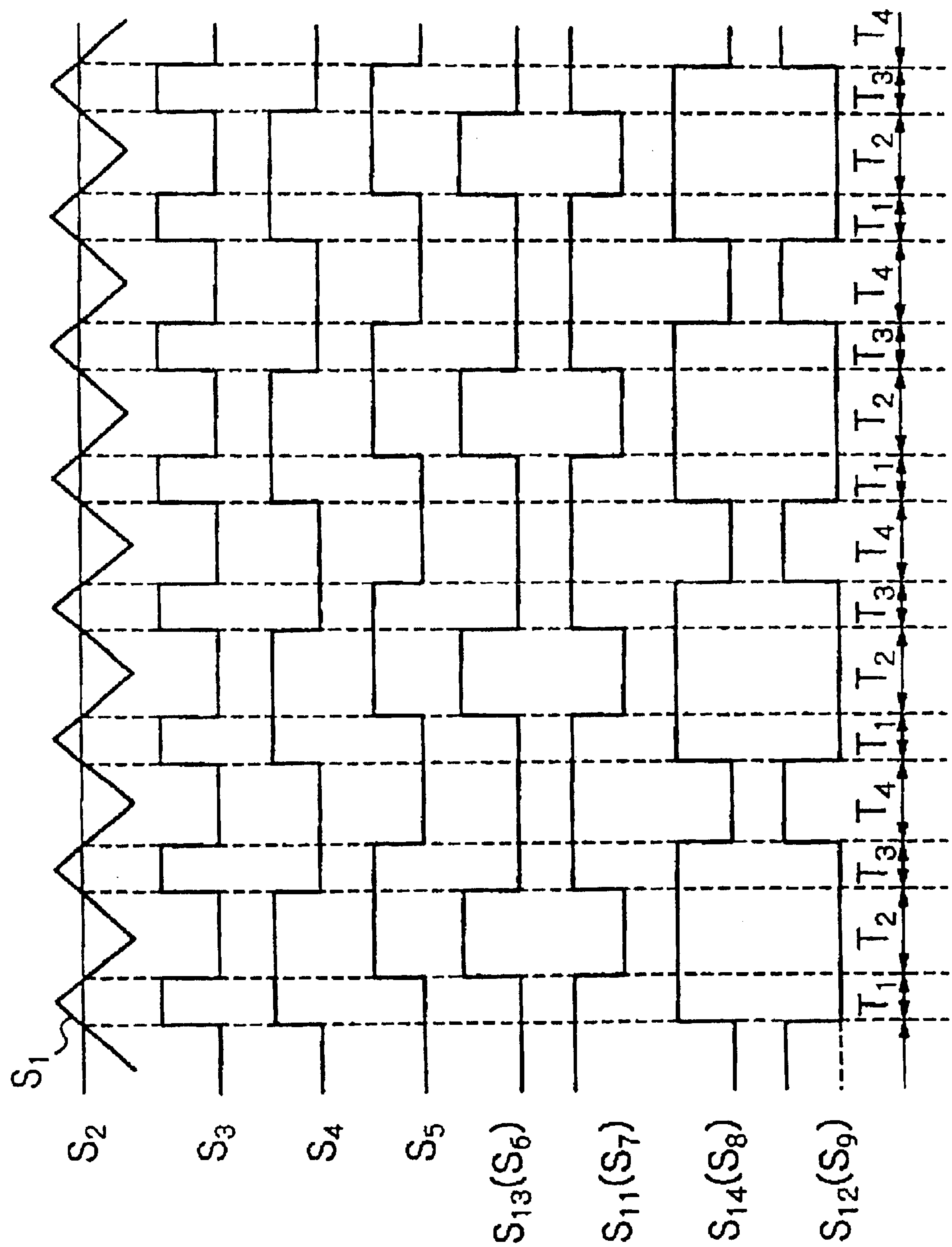

FIG. 4

H-BRIDGE MOTOR DRIVING CIRCUIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an H-bridge motor driving circuit for controlling a DC motor using pulse width modulation (PWM).

2. Description of the Related Art

One general motor driving circuit for controlling a DC motor to rotate selectively in normal and reverse directions is an H-bridge motor driving circuit which has an H-shaped bridge circuit comprising four transistors and a DC motor. The four transistors are turned on and off to energize, de-energize, and rotate the DC motor selectively in the normal and reverse directions.

FIG. **1** of the accompanying drawings shows a typical conventional H-bridge motor driving circuit.

As shown in FIG. **1**, the conventional H-bridge motor driving circuit comprises H-bridge output circuit **10**, triangular wave oscillator **11**, PWM comparator **12**, inverter **13**, and control circuit **14**.

H-bridge output circuit **10** has MOS transistors Q_1, Q_2 each having a drain connected to the positive terminal of a DC power supply E, a source connected to the circuit board, and a gate supplied with control signals S_{11}, S_{12}, respectively, for turning on and off MOS transistors Q_1, Q_2, and MOS transistors Q_3, Q_4, each having a drain connected to the sources of MOS transistors Q_1, Q_2, respectively, a source connected to the circuit boards and a ground potential point to which the negative terminal of the DC power supply E is connected, and a gate supplied with control signals S_{13}, S_{14}, respectively, for turning on and off MOS transistors Q_3, Q_4. Motor M is connected between the junction between MOS transistors Q_1, Q_3 and the junction between MOS transistors Q_2, Q_4. Parasitic diodes D_1 through D_4 exist at the junctions between the sources of MOS transistors Q_1 through Q_4, the circuit board, and the drains of MOS transistors Q_1 through Q_4.

Triangular wave oscillator **11** generates triangular wave signal S_{21}.

PWM comparator **12** compares triangular wave signal S_{21} from triangular wave oscillator **11** with constant-level signal S_{22}, and outputs PWM pulse signal S_{23}.

Inverter **13** inverts pulse signal S_{23} from PWM comparator **12** into pulse signal S_{24}.

Control circuit **14** is supplied with pulse signals S_{23}, S_{24}, power-supply-level signals S_{25}, S_{26}, and rotation control signal S_0, and outputs signals S_{25}, S_{24}, S_{26}, S_{23} as control signals S_{11} through S_{14} for MOS transistors Q_1 through Q_4.

Operation of the conventional H-bridge motor driving circuit shown in FIG. **1** will be described below with reference to a timing chart of FIG. **4** of the accompanying drawings.

Triangular wave signal S_{21} generated by triangular wave oscillator **11** and constant-level signal S_{22} are supplied to comparator **12**, which generates PWM pulse signal S_{23}. PWM pulse signal S_{23} is inverted into signal S_{24} by inverter **13**. Signals S_{23}, S_{24}, power-supply-level signal S_{25}. and ground-level signal S_{26} are supplied to control circuit **14**, and then applied as respective control signals S_{14}, S_{12}, S_{11}, S_{13} to the gates of MOS transistors Q_4, Q_2, Q_1, Q_3, respectively. It is assumed that MOS transistors Q_1, Q_4 are energized , and MOS transistor Q_4 is PWM-controlled. During period T_1, signals S_{23}, S_{25} are high and MOS transistors Q_1, Q_4 are turned on, causing a current to flow through motor M. During period T_2, signals S_{24}, S_{25} are high and MOS transistors Q_1, Q_2 are turned on, entering a regenerative mode to produce a regenerative current flowing through a loop from motor M to MOS transistor Q_2 to MOS transistor Q_1 to motor M (in case of an inductive load). In case of a resistive load, the MOS transistors are not conducted.

The conventional H-bridge motor driving circuit described above is disadvantageous in that since MOS transistor Q_1 is energized at all times and hence a current flows through MOS transistor Q_1 at all times, a large amount of electric power needs to be supplied to the H-bridge motor driving circuit, which generates a large amount of heat and hence suffers poor reliability. The H-bridge motor driving circuit is necessarily of increased cost as it needs a high-performance device such as a low-on-resistance MOSFET or a low-saturation-voltage transistor for reducing the amount of generated heat.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an H-bridge motor driving circuit which includes a circuit arrangement for distributing an amount of applied electric power among a plurality of transistors to equalize the amounts of heat generated by the transistors.

To achieve the above object, an H-bridge motor driving circuit according to the present invention comprises, connected between a PWM comparator and a control circuit, first and second frequency dividers for frequency-dividing, by 2, an output signal from the PWM comparator with positive-going edges and negative-going edges, respectively, thereof, an AND gate for ANDing an output signal from the first frequency divider, an OR gate for ORing the output signal from the first frequency divider and the output signal from the second frequency divider, and first and second inverters for inverting an output signal from the AND gate and an output signal from the OR gate, respectively.

The control circuit applies an output signal from the first inverter, an output signal from the second inverter, the output signal from the AND gate, and the output signal from the OR gate to the gates of first, second, third, and fourth MOS transistors, respectively.

During a first period, the first and second transistors are turned on, and the second and third transistors are turned off, causing a current to flow through a motor. During a next second period, the third and fourth transistors are turned on, and the first and second transistors are turned off, causing a regenerative current to flow through the motor. During a next third period, the MOS transistors are turned on and off in the same manner as during the first period, causing a current to flow through the motor. During a final fourth period, the first and second transistors are turned on, and the third and fourth transistors are turned off, causing a regenerative current to flow through the motor.

In a regenerative mode, the first and second MOS transistors, and the third and fourth MOS transistors are alternately turned on. Therefore, the amount of applied electric power is distributed among the MOS transistors, thus equalizing the amounts of heat generated by the MOS transistors.

The above and other objects, features, and advantages of the present invention will become apparent from the following description with reference t the accompanying drawing s which illustrate an example of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a circuit diagram of a conventional H-bridge motor driving circuit;

FIG. **2** is a diagram showing waveforms in various portions of the conventional H-bridge motor driving circuit shown in FIG. **1**;

FIG. **3** is a circuit diagram of an H-bridge motor driving circuit according to the present invention; and

FIG. **4** is a diagram showing waveforms in various portions of the H-bridge motor driving circuit shown in FIG. **3**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. **3**, an H-bridge motor driving circuit according to an embodiment of the present invention comprises triangular wave oscillator **1**, PWM comparator **2** for comparing triangular wave signal S_1 and an input signal S_2 with each other, frequency dividers **3**, **4** for frequency-dividing, by 2, output signal S_3 from PWM comparator **2** with positive-going edges and negative-going edges, respectively, thereof, AND gate **5** and OR gate **6** for ANDing and ORing, respectively, output signals S_4, S_5 from frequency dividers **3**, **4**, inverters **7**, **8** for inverting output signals S_6, S_8, respectively, from AND gate **5** and OR gate **6** into respective signals S_7, S_9, H-bridge output circuit **10**, and control circuit **9** for outputting control signals S_{11}, S_{12}, S_{13}, S_{14} from signals S_6, S_7, S_8, S_9 and rotation control signal S_0 indicative of whether motor M spins in a normal or reverse direction, to turn on and off MOS transistors Q_1, Q_2, Q_3, Q_4. H-bridge output circuit **10** is of an arrangement identical to the arrangement of H-bridge output circuit **10** of the conventional H-bridge motor driving circuit shown in FIG. **1**.

Operation of the H-bridge motor driving circuit according to the present embodiment will be described below with reference to FIG. **4**. FIG. **4** shows waveforms in various portions of the H-bridge motor driving circuit at the time motor M rotates in the normal direction. When motor M rotates in the reverse direction, signals S_{13}, S_{11} and signals S_{14}, S_{12} are switched around.

Triangular wave signal S_1 generated by triangular wave oscillator **1** and input signal S_2 are supplied to PWM comparator **2**, which generates PWM pulse signal S_3. Frequency dividers **3**, **4** frequency-divide, by 2, PWM pulse signal S_3 from PWM comparator **2** with positive-going edges and negative-going edges, respectively, thereof. Specifically, frequency divider **3** frequency-divides PWM pulse signal S_3 with positive-going edges thereof, producing pulse signal S_4, and frequency divider **4** frequency-divides PWM pulse signal S_3 with negative-going edges thereof, producing pulse signal S_5. These pulse signals S_4, S_5 have the same frequency as the frequency of triangular wave signal S_1 output from triangular wave oscillator **1**, and are shifted out of phase with triangular wave signal S_1 by the period of the high level of PWM pulse signal S_3. Pulse signals S_4, S_5 output from frequency dividers **3**, **4** are applied to AND gate **5** and OR gate **6**, respectively, which generate pulse signals S_6, S_8, respectively. Pulse signals S_6, S_8 are then inverted by respective inverters **7**, **8** into inverted pulse signals S_7, S_9. Pulse signals S_6, S_7, S_8, S_9 are supplied to control circuit **9**, which apply them as control signals S_{13}, S_{11}, S_{14}, S_{12} to the gates of MOS transistors Q_3, Q_1, Q_4, Q_2, respectively.

It is assumed that MOS transistors Q_1, Q_4 are energized. With the conventional H-bridge motor driving circuit, only MOS transistor Q_1 or only the MOS transistor Q_4 is switched to drive motor M according to PWM. According to the present invention, MOS transistors Q_1, Q_4 are alternatively switched to drive motor M according to PWM. Pulse signal S_7 is applied as the gate signal S_{11} for MOS transistor Q_1, pulse signal S_9 is applied as the gate signal S_{12} for MOS transistor Q_2, pulse signal S_6 is applied as the gate signal S_{13} for MOS transistor Q_3, and pulse signal S_8 is applied as the gate signal S_{14} for MOS transistor Q_4. One sequence of operating patterns of MOS transistors Q_3, Q_1, Q_4, Q_2 is indicated in periods T_1 through T_4. States of signals and MOS transistors in each of periods T_1 through T_4 will be described below.

During period T_1, pulse signals S_7, S_8 are high. As a result, MOS transistors Q_1, Q_4 are turned on, and MOS transistors Q_2, Q_3 are turned off, causing a current to flow through motor M.

During period T_2, pulse signals S_6, S_8 are high. As a result, MOS transistors Q_3, Q_4 are turned on, and MOS transistors Q_1, Q_2 are turned off. At this time, H-bridge output circuit **10** enters a regenerative mode to produce a regenerative current flowing through a loop from motor M to MOS transistor Q_4 to MOS transistor Q_3 to motor M (in case of an inductive load). In case of a resistive load, the MOS transistors are not conducted.

During period T_3, pulse signals S_7, S_8 are high. As a result, MOS transistors Q_1, Q_2 are turned on, and MOS transistors Q_3, Q_4 are turned off. At this time, H-bridge output circuit **10** enters the regenerative mode to produce a regenerative current flowing through a loop from motor M to MOS transistor Q_2 to MOS transistor Q_1 to motor M (in case of an inductive load). In case of a resistive load, the MOS transistors are not conducted.

While a preferred embodiment of the present invention has been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.

What is claimed is:

1. An H-bridge motor driving circuit comprising:

an H-bridge output circuit for driving a motor, said H-bridge output circuit including first and second MOS transistors having sources and drains, either of which are connected to a first terminal of a DC power supply, parasitic diodes existing between the sources and the drains and to which a voltage of the DC power supply is applicable in a reverse direction, and gates for being supplied with control signals to control conduction/non-conduction of the first and second MOS transistors, and third and fourth MOS transistors having sources and drains, either of which are connected to the other of the sources and the drains of said first and second MOS transistors and others of which are connected to a second terminal of the DC power supply, parasitic diodes existing between the sources and the drains and to which the voltage of the DC power supply is applicable in a reverse direction, and gates for being supplied with control signals to control conduction/non-conduction of the third and fourth MOS transistors, said motor being connected between a junction between said first and third MOS transistors and a junction between said second and fourth transistors;

a triangular wave oscillator for generating a triangular wave signal;

a PWM comparator for comparing said triangular wave signal with a constant-level signal;

first and second frequency dividers, each frequency-dividing, by 2, an output signal from said PWM comparator with positive-going edges and negative-going edges, respectively, thereof;

an AND gate for ANDing an output signal from said first frequency divider and an output signal from said second frequency divider;

an OR gate for ORing the output signal from said first frequency divider and the output signal from said second frequency divider;

first and second inverters, each inverting an output signal from said AND gate and an output signal from said OR gate, respectively; and

a control circuit for applying an output signal from said first inverter, an output signal from said second inverter, the output signal from said AND gate, and the output signal from said OR gate to the gates of the first, second, third, and fourth MOS transistors, respectively.

* * * * *